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# The (R)evolution of China: Offshore Wind Diffusion

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**Abstract:** This research presents an industry level gap analysis for Chinese offshore wind, which serves as a way to illuminate how China may fast track industry evolution. The research findings provide insight into how the Chinese government strongly and systematically decrees state-owned Chinese firms to expand into overseas markets to speed up learning efforts. Insights are offered regarding the nation-level strategic plans and institutional support policies mobilized by China in order to be able to conquer market shares internationally by building a strong home market and then facilitating an end-to-end and fully financed export solution. This is interesting in itself and in particular so because it now also includes complex billion-dollar megaprojects such as turnkey offshore wind farm assets with an expected lifespan of 30+ years. Research findings are provided on how European and Chinese firms may successfully forge long-term alliances also for future Chinese wind energy export projects. Examples of past efforts of collaboration not yielding desired results have been included as well. At policy level, recommendations are provided on how the evolution of the Chinese offshore wind power industry can be fast-tracked to mirror the revolutionary pace, volume, and velocity which the Chinese onshore wind power industry has mustered.

**Keywords:** China; offshore wind; gap analysis; industry maturity; mergers & acquisitions; central state-owned enterprises; turnkey project export; industry evolution; industry life-cycles

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## 1. Introduction

From an industry evolution and maturity perspective, the Chinese *onshore wind* market had developed with revolutionary pace based on policy stimulus from the Chinese government [1]. However, challenges in terms of the operations of the onshore assets had started to emerge [2]. By the end of 2015, this phenomenon of operational challenges deriving from the onshore wind turbine generator (WTG) technological trajectory of Chinese wind turbine original equipment manufacturers (OEMs), as well as a different operations and maintenance (O&M) philosophy, was being debated openly at conferences and industry events [3] as onshore asset performance negatively impacted profitability of large wind farm operators. This open debate seemed to be somewhat at odds with the general culture of trying to avoid admitting to mistakes and ‘losing face’ which indicates how significant the operational and ensuing financial challenges are.

Similarly, *offshore wind* in China was originally slated to move forward with an equally revolutionary pace. The question as to whether this was indeed realistic was raised by very few scholars [4,5]. General wind energy policy settings aimed mainly at the onshore industry were organized both centrally [1,6] and subsequently for offshore wind also with opportunities to top up the central subsidy schemes regionally at a provincial level [3]. However, the offshore wind industry did not evolve as quickly as expected and not in line with targets outlined in the official Five Year

Plans. As of the end of 2016, a total of 1.6 giga-Watt (GW) capacity had been grid connected in China [7] compared to original targets of 5 GW by 2015 and 30 GW by 2020 [4,5].

In Europe, both the onshore and offshore wind industries have developed technologically over a longer time trajectory than what has been the case in China. For onshore wind, the Danish government decided to support the emergence of the industry in 1979 [8,9] and as of the end of 2016, Europe enjoyed 148.7 GW of grid connected onshore wind capacity. Conversely for offshore wind, ministerial reports from 1983 and 1988 on renewable energy in a Danish context ultimately led to the erection of the world's first offshore wind farm (OWF) in 1991, Vindeby [10]. The experiences with offshore wind from the Vindeby OWF and its early successors such as Tunø Knob and Horns Reef 1 have displayed significant differences in the technological trajectory of WTGs erected onshore compared to those erected offshore [3,10] as well as 'learning the hard way' differences in cost composition [11–13]. From an industry evolution perspective, it is important to note that by now, Europe has witnessed a full cradle-to-grave evolutionary path cycle within offshore wind as evidenced by the Vindeby OWF as this has just been decommissioned during 2017 [14]. The Vindeby OWF was comprised of 11 WTGs each with a capacity of 0.45 mega-Watt (MW) and the OWF was located between 1.5 and 3 km from shore in Lolland, Denmark. Over the 25-year period since the grid connection of the Vindeby OWF in 1991, a total of 12.6 GW of offshore wind had been erected and grid connected in Europe [15] with OWFs becoming GW-sized in terms of capacity while moving further from shore into deeper waters [12,13,16]. By 2024 and 2025, the first OWFs free of government subsidies will have been constructed and grid connected in Germany [17,18]. This is a result of the cost reduction path started in 2012 by the United Kingdom government and the world's leading offshore wind farm operator, Ørsted, formerly DONG Energy Wind Power [12,19].

In order to pick up speed in terms of offshore wind diffusion and mirror the revolutionary pace of Chinese onshore wind energy diffusion, it could be relevant for China to look towards European offshore wind constituencies in terms of experiences, knowledge, and skills needed to fast-track the industrial evolution. However, memories of the introduction of local content rules [1] to the Chinese onshore wind market are—as presented in this research—still on the forefront of the historical context viewed by some European firms participating in the early part of the onshore wind industrial revolution in China.

The next section will present our research design, the key academic terms of reference (industry maturity, state-owned enterprises, and mergers and acquisitions), and the background for our case study. Section 3 will present the method applied in more detail. Section 4 will detail the findings of the analysis and in Section 5 we will present the results of the research. In Section 6, we discuss the results of our findings. Section 7 concludes and provides suggestions to guide the work efforts rendered by other researchers.

## 2. Research Objectives, Key Academic Terms, and Case Study Introduction

The specific contextual setting used as the inroads to empirical data collection in our case study is based on the prior knowledge and experience of the research team which is comprised of the areas of shipping, logistics, and supply chain management (SCM), hereinafter jointly referred to as 'logistics' or jointly 'shipping and logistics', depending on the context.

### 2.1. Research Objectives

With this as a backdrop, our China offshore wind case study was initiated in 2013 and originally set out to analyze the following three research questions regarding the offshore wind industry in China:

- (1) Are the 12th Five Year Plan offshore wind targets of 5 GW and 30 GW of offshore wind power in operation realistically implementable by the prescribed plan deadlines of 2015 and 2020 respectively?
- (2) With the onshore (r)evolution of wind energy in China, why has the evolution of offshore wind been seemingly a lot slower?

- (3) What role, if any, does logistics, as defined by Poulsen and Hasager [12], play in this slower offshore wind diffusion in China?

A number of *key academic terms* are important to define in order to set the scene for the research. These academic terms will be presented in Sections 2.2–2.4 while an introduction to our case study will follow immediately thereafter in Section 2.5.

## 2.2. Industry Maturity

According to several extensive reviews of available academic literature, the metaphor of life cycles was born in the 1950s within the marketing field of study at a product and services level and was referred to in general as the product life cycle (PLC) theory stream [20,21]. The notion of PLC was that a product or service generally experiences four phases of development which evolve over time as the product matures and these four phases were [20–22]:

- (1) embryonic
- (2) growth
- (3) mature, and ultimately
- (4) decline.

The PLC theory is generally understood within management literature to be the antecedent of what is now commonly referred to as the industry life cycle (ILC) theory stream [20,23,24] which uses the same four phases as PLC theory to describe the trajectory of evolution of an industry, the business ecosystem lifecycle, or the trajectory of *industry maturity*. Although described by scholars much earlier according to Andersen et al. [22], the seminal work of innovation scholars Abernathy and Utterback [23] is for the most part considered the foundation of the ILC theory stream.

Interestingly, the prior work of the same authors [25] identified that process innovation by a firm's suppliers signifies product maturity, which means that product innovation precedes process innovation. The underlying industry maturity related taxonomy is that products and services are usually sold to customers in a market place where the market and customers signify demand and the supply is provided by an industry which again is comprised of different firms [21,22]. Whereas the relation between the market and industry is well described in literature in terms of market mechanics, the co-evolution of industry and firms has long been discussed at both a regional/national macro level, at an industry meso level, and at a firm micro level [22]. Essentially a discussion of whether the industry shapes firms or firms shape the industry, the ILC literature works at several levels:

- First, the ILC theory stream deals with several attributes and groupings of characteristics of the industry or firms therein which can be observed to change over time as the industry evolves through the life cycle phases. Findings from literature have been grouped in several literature reviews [20,21,24] with the general objective that observations may then determine where in the ILC trajectory an industry is. As an example, Jensen and Thoms [21] define five groupings of characteristics with a total of 17 different sub-attributes that evolve and change over the life cycle of an industry based on a literature review that also includes a detailed review of the two prior literature reviews [20,24].
- Second, the ILC theory stream is also concerned with how one ILC phase ends to give way to the next phase in order for firms to understand when for example the growth phase ends and the maturity phase commences for example based on the emergence of a dominant design [26]. General opinions on the behaviour of different industries have been formed on this topic by reviewing literature [20] with the result that certain industry growth rates imply the shift from e.g., the entrepreneurial regime/embryonic ILC phase to the growth ILC phase. As the ILC theory stream is in itself still in the process of maturing [20,24], terminology pertaining to the different ILC phases is somewhat ambiguous and the timing of some critical ILC events like 'the shake-out' is sometimes noted to be taking place in different ILC phases [21].
- Third, ILC literature is concerned with how firms can be successful in an industry and how an industry survives or declines and ultimately dies out. Several events in the ILC phases are of

interest such as entry timing of firms/first mover advantage, survival of the shake-out, and the emergence of a dominant design [21]. In addition, other factors such as the technological trajectory, prior experience, and prior industry affiliation [22] are also understood to be of importance. From the ILC literature it is clear that not all events happen across all industries. For example, a shake-out may not occur because of situations, such as spin-offs or new niches emerging [21] or the formation of sub-markets [27]. Similarly, the industry may stay in the mature ILC phase and never enter the decline phase by virtue of events such as dematurity, renewal, and re-cycles which counter-act the standard ILC trajectory pattern [21,22].

Based on the three levels at which the ILC body of literature works, industry evolution, industry maturity, and the movement of an industry and the firms within the industry along the ILC trajectory are important frameworks to consider when wind energy is the topic of discussion. The wind industry is generally considered to be less industrialized compared to e.g., the automotive industry, truck assembly, or airplane assembly [28,29], the construction industry [30–32], the oil and gas industry [33], similar turn-key project industries [34,35], and one-of-a-kind construction projects [34,36].

Furthermore, differences in industry maturity between the onshore and offshore wind markets exist with the offshore wind industry generally understood to be less evolved than onshore wind [3,11]. As such, the strategic focus of the wind industry and its constituencies is likely to switch from product innovation among the key firm constituencies to process optimization by suppliers [25,37], such as the shipping and logistics firms serving the wind industry, in the coming years. To drive this change and trajectory of industry maturity, platform leadership is required [38,39] along with the emergence of a dominant design [26].

### 2.3. Chinese State-Owned Enterprises

In China, *state-owned enterprises* (SOEs) make up a significant part of the economy. These types of Chinese firms have been subject to much research such as the overall government reform of the SOEs [40,41], public reporting/disclosures [42], and corporate governance [43].

Usually owned by the local governments [44] in the different provinces/municipalities and referred to as local SOEs (LSOEs), many comparisons have been made between SOEs and non-communist owned firms in OECD countries on topics as diverse as initial public offering (IPO) stock performance [45], due diligence and accounting challenges [46], executive compensation [47], and corporate social responsibility reporting [42].

A number of approx. 100 very large and/or nationally important SOEs are managed/overseen centrally by the State-owned Assets Supervision and Administration Commission of the State Council (SASAC) at a central government level and these firms are referred to as the Central SOEs (CSOEs). SASAC and CSOEs are defined as well as discussed in a number of papers as these papers review topics, such as firm ownership structure [43], stock market listing [45], financial performance [48], audit quality [49], and social as well as environmental reporting [42].

Many papers dealing with SASAC and CSOEs cite that SASAC policies are first implemented by CSOEs and in many cases subsequently adopted by the stock exchanges and LSOEs to a varying degree depending on provincial adaptation and individual firm situations [42,43,49]. As we proceed to review the Chinese wind industry, understanding the SOE set-up in China is an important prerequisite both at a national and province/local level.

### 2.4. Mergers and Acquisitions

Within the strategic management literature [50–52], growth and value creation within firms are examples of strategies that may be planned and implemented either organically or through *mergers and acquisitions* (M&A).

In terms of a definition of M&A, many exist and it is generally understood that a ‘merger’ commonly implies a combination of two firms that are relatively equal whereas an ‘acquisition’ is a type of merger where one firm buys a controlling interest in another [53]. Different transaction types

exist including joint-ventures (JVs), Public-Private Partnership (PPP) JV types, leveraged buyouts, spin-offs, and different kinds of partial or full acquisitions such as asset purchase transactions or share purchase agreements [54].

In terms of key terminology and language of the M&A field, a bidder firm is interested in a target firm and a deal between the two firms is the event that marks that M&A transaction is successfully consummated [55]. Both bidders and targets may be privately held, including family owned firms, or publicly traded and the transacting party could be the firm itself or subsidiaries [55]. The acquirer may choose to pay an acquisition premium for different reasons and here, revenue and cost related synergies may play an important role in terms of target firm valuation [56]. Payment methods include payments in cash, stock, and various kinds of bank related financing [55].

The M&A process is complex and can generally be segmented into what happens before and after the M&A transaction itself [57]. Phenomena such as deal antecedents (why acquire?), drivers behind the transaction (what is the strategy?), and the decision making process leading to the deal (how did the deal come about?) are generally viewed by academia on the one hand. On the other hand, the consequences of the deal, as a result of the integration, are generally seen by academic scholars as the outcome post deal transaction, including performance and value distribution [55,58]. It is, however, generally understood by scholars and practitioners alike that the M&A process can advantageously be sub-divided into several phases.

The M&A process is complex because it starts at the level of a firm's strategic goals, both from the perspective of the acquirer and the to-be-acquired firm [50,51]. The subsequent M&A process steps include identifying and selecting the target(s) on the part of the bidder as well as deciding to sell on the part of the target, the negotiation process, due diligence, deal announcement, deal completion, post-merger integration (PMI), performance measurement, and hopefully value creation [53]. M&A process complexity is generally understood within academia to intensify in cross-border M&A deals, where the target is located in a different country than the country of the acquirer's head office, compared to 'within-country' or domestic M&A transactions [53,55]. Much academic literature has traditionally been quantitative in nature and has to a large extent concentrated on M&A activity of publicly traded firms in the United States (US) mainly because M&A activity has historically been more intense in the US and also because of data availability [55].

In the US, the size of the country and characteristics of the different M&A waves [55,59] has meant that much M&A activity has traditionally been focused on domestic deals within the country and here, the M&A process has been broadly accepted based on Reed and Lajoux [54], i.e.,:

- (1) planning and finding,
- (2) valuation and pricing,
- (3) financing and refinancing,
- (4) structuring M&A/buyout transactions,
- (5) the due diligence inquiry,
- (6) pension, labour, and compensation concerns,
- (7) negotiation of the letter of intent and the acquisition agreement,
- (8) deal closing, and
- (9) PMI.

Conversely, this seminal work of Reed and Lajoux [54], in a US setting, attributed only a small focus to M&A transactions with an international aspect, i.e., cross-border M&A deals.

According to Zhu and Zhu [53], motivations behind M&A deals can be to integrate the two firms to create value and increase performance of the combined entity going forward (strategic M&A deals) or for a financial investor to acquire a target and subsequently sell the acquired firm at a higher price (financial M&A deals). From a value perspective, most M&A transactions create an uneven distribution of the value generated where target firms obtain the largest share of the value and it is largely understood within academia that the acquirers rarely create value from M&A transactions [55]. On the part of target firms, strategic management options for value creation often include the choice of a stock market listing or going through the process of finding a strategic buyer or financial

investor. Whereas separate bodies of literature exist on IPOs and M&A respectively within academia, the two literature streams unfortunately seldom merge or cross-reference [55]. On the part of acquirers, performance is generally measured using defined terms such as cumulative abnormal returns as measured by increases seen over time in the stock prices of the acquiring firm after the deal announcement event or by calculating the acquisition premium paid [55,58]. In their seminal work, Haspeslagh and Jemison [57] suggested that it is often decisions in the pre-acquisition stage that cause the many negative post-merger outcomes. According to the extensive reviews of Halebian et al. [55] and Zhu and Zhu [53], scientists increasingly focus on researching the value creating conditions that make up the minor portion of deals where value is created for acquirers.

Due to the strategic importance put on different kinds of M&A initiatives orchestrated by the Chinese government at an industry level especially using the CSOEs as the execution instruments, having a general understanding of M&A is therefore important as we review how China is approaching the wind energy industry in the offshore segment. This is contrasted and correlated with the approach China took at an earlier stage for onshore wind.

### *2.5. China Offshore Wind Case Study Introduction*

This research is very timely and coincides with two other major studies of the Chinese wind market, namely those of Kirkegaard [2] for onshore wind and Korsnes [5] for offshore wind. When it comes to Asian case studies, especially the use of an existing personal network within the shipping and logistics industry as a ‘bridge’ into the right people has been very useful also for this research. In addition, the network of friendly people from other industry segments has been used effectively to create an initial wind energy industry ‘platform’ of relationships to operate from. These people from other industry segments were effectively acting as similar ‘bridges’ to get to the right people within the wind energy shipping/logistics/SCM vertical. From this initial ‘platform’, additional ‘bridges’ then had been created in order to have a solid foundation for the Chinese case study efforts presented as part of this research to be based on and further developed from.

One of the challenge with interviewing in Asian case study settings is one of culture and the Asian mentality’s fear of ‘loosing face’: Within the Asian culture, participating in a case study means the risk that the interviewee willingly or unwillingly expose a co-worker/superior by saying something that may somehow affect them and this Asian cultural challenge is not always fully described in case study method literature [60]. The interviewee may also risk ‘loosing face’ by being quoted for something which could later be contested by others as being wrong or only partially true. These cultural barriers and the inherent fear of ‘loosing face’ make the interview part of case study work in Asia particularly challenging. Nevertheless, a Chinese case study [61] with both semi-structured and formal interviews [62] has formed a major part of this research.

The Chinese offshore wind case study consists of a total of 143 encounters of which 103 are interviews and 40 are participant observation site visits (see Table 1). The case study empirical data collection efforts have been divided into primary and secondary empirical data collection efforts with 102 and 41 encounters respectively. 88 of the 103 interviews as well as 6 of the 40 participant observation site visits were conducted using a semi-structured interview process [62] with interview and site visit guides that were iteratively developed. This initial work led to a more formalized embedded case study opening up as part of the primary empirical data collection efforts with support from a Chinese WTG OEM [61]. The embedded case study consisted of 15 formal interviews supplemented by 34 participant observation site visits that enhanced the validity and reliability of the empirical data collected as the site visits included more in-depth interaction with the interviewees and often entailed long car rides across vast distances and many hours spent together.

**Table 1.** Summary of all encounters of the China offshore wind case study included in this research.

China Offshore Wind Case Study— Empirical Data Collection Efforts	Interviews	Participant Observation Site Visits	Total Number of Encounters
Secondary data gathering—semi-structured interviews	41	0	41
Primary data gathering—initial semi-structured “bridge” interviews	47	6	53
Primary data gathering—15 formal interviews	15	34	49
	103	40	143

Overall, the China offshore wind case study has five Asia visits included as part of the primary empirical data collection efforts during the lifespan of 33 months comprising this research (see Table 2). During the five trips, approx. 2 months were spent in China itself. Shipping and logistics was used as the entry point but a more elaborate interview guide had been developed to cater for the research questions outlined in 2.1 above.

**Table 2.** Trips to Asia and China as part of the primary empirical data collection efforts of this research.

Trip Timing	Geographical Scope	Total Time Spent	Interviews in China	Participant Observation Site Visits	Earlier Dissemination Efforts
September, 2013	China, Hong Kong, Singapore	2 ½ weeks	32 (semi-structured)	4	[11]
February, 2014	South Korea, China, Singapore	2 ½ weeks			
October, 2014	China	2 weeks	15 (semi-structured)	2	N/A
July, 2015	Taiwan, South Korea, China	2 ½ weeks	15 (structured, with bi-lingual interview guide)	34	[3]
October, 2015	China	2 weeks			

In addition, an associate researcher spent two months in China during the first half of 2014 and this is considered the secondary empirical data collection efforts of this China offshore wind case study. During the time spent in China, the associate researcher carried out a total of 41 semi-structured interviews [62] which form part of the secondary empirical data collection efforts presented in Section 4.4 of this research. The research design for these interviews performed by the associate researcher was different in nature inasmuch as these secondary empirical data collection interviews focused more on non-Chinese nationals and non-Chinese firms in China as this was the easier approach for the associate researcher who did not have prior experience with the Chinese culture [60] before the visit to China. In addition, the associate researcher did not have a prior network in China nor any available ‘bridges’ to forge relations and therefore had to utilize the network and ‘bridges’ available from the primary research efforts of this research. As a result, the secondary data collection efforts were narrow in terms of the reach.

The research design of the associate researcher was duly correlated with the overall research design of this China research and the results form part of the overall case study and research analysis presented here (from a funding perspective, the work performed by the associate researcher was structured as part of a separate endeavour not covered by the funding mentioned in the acknowledgements section below).

### 3. Method

Culturally, trust is gained through relationships in China. This means that in order to get to the right person and be able to obtain empirical data of use in academic research, a fairly sizeable investment in relationship creation is required [3,11]. For our Chinese empirical data collection and



research design (see Section 2.5 above), the first three primary empirical data collection visits to China were focused on building the right relationships and getting to the right people by means of other people acting as the ‘bridge’ to get there [11]. During the fourth visit, the right people had been identified and a ‘shepherd’ had emerged to lead the way in the form of a leading Chinese WTG OEM and this became our embedded case study. As a consequence, interviewing could now take place in earnest with a proper bilingual English/simplified Chinese character interview guide [60,62] constructed from knowledge gathered during the prior visits [3].

### *3.1. Primary Empirical Data Collection Efforts in China*

During the fourth and fifth visits to China, a total of 15 structured and formal interviews took place during using the bilingual interview guide. The interview process in China was slightly less rigorous than that applied e.g., for the Ørsted (formerly DONG Energy Wind Power) logistics R+D strategy paper process [12] conducted in parallel with the China interview process as compared and contrasted by Poulsen and Lema [3]. The China interviews lasted from 45 min to 7.5 h, 2–8 people including observers and/or translators participated in the formal interview meetings, and audio taping was either not permitted or not practically feasible. 12 of the 15 formal interviews in China included an element of participant observation site visits and in some cases, this enhanced the interview for example because of a car ride for several hours with only 1 or 2 English speaking persons where more informal dialogue could be had. Details of the primary research encounters have been detailed in Table 3.

Table 3. Primary empirical data collection efforts in China.

Research Design	Interviews	Participant Observation Site Visits	Total Encounters	Number of Visits to China	Timing of Visits			
Initial semi-structured “bridge” interviews	47	6	53	3	2013–2014			
15 formal interviews	15	34	49	2	2015			
	62	40	102	5	-			
Initial Semi-Structured “Bridge” Interviews	Developers	WTG OEMs	Shipping/logistics /ports	BOP Manufacturing	Sub-Suppliers	Offshore Wind Farm	Other Supply Chain <sup>1</sup>	Total
Top management in China	-	-	6	-	4	-	5	15
Middle Management in China	-	4	14	1	3	-	7	29
Execution layer in China	-	-	-	-	-	-	3	3
Site layer in China	-	-	-	-	-	-	-	0
Total	0	4	20	1	7	0	15	-
Grand total	47	-	-	-	-	-	-	-
15 Formal Interviews	Developers	WTG OEMs	Shipping/logistics /ports	BOP Manufacturing	Sub-Suppliers	Offshore Wind Farm	Balance Supply Chain <sup>2</sup>	Total
Top management in China	-	-	2	1	3	-	-	6
Middle Management in China	2	1	2	1	1	-	2	9
Execution layer in China	-	-	-	-	-	-	-	0
Site layer in China	-	-	-	-	-	-	-	0
Total	2	1	4	2	4	0	2	-
Grand total	15	-	-	-	-	-	-	-
Participant Observation Visits	Developers	WTG OEMs	Shipping/logistics /ports	BOP Manufacturing	Sub-Suppliers	Offshore Wind Farm	Balance Supply Chain <sup>2</sup>	Total
As part of initial semi-structured bridge interview process	-	2	2	1	-	-	1	6
As part of process for 15 formal interviews	1	6	8	4	6	2	7	34
Total	1	8	10	5	6	2	8	-
Grand total	40	-	-	-	-	-	-	-
Grand grand total	102	-	-	-	-	-	-	-

<sup>1</sup> Other supply chain includes education, cluster associations, other support firms, etc.<sup>2</sup> Balance supply chain includes China Wind Power conference, education, cluster associations, other support firms, etc.

Besides the 15 formal interviews in China, a total of 34 participant observation site visit encounters were organized in the form of site visits to the actual Chinese supply chain locations such as WTG/balance of plant (BOP) component manufacturing facilities, shipyards, ports, and OWF sites (of which one such OWF site was visited offshore two times during the embedded case study [3]). This took the total number of participant observation site visits in China to 40 during the embedded case study primary empirical data collection efforts over the 5 trips to China (see Table 4 for a select overview of key participant observation site visits).

**Table 4.** Participant observation examples from the primary empirical data collection efforts—site visits during the five trips performed to China.

No.	Timing within Research	Site	Timing of Visit	Location	Rationale and Relevance
1	First three China trips	ZPMC Offshore Wind	September, 2013	Nantong, Jiangsu	Port-side offshore wind facility built in accordance with the 12th Five Year Plan
2	First three China trips	Goldwind Offshore Base	September, 2013	Dafeng, Jiangsu	Offshore wind WTG manufacturing plant of key OEM
3	First three China trips	Dafeng port	September, 2013	Dafeng, Jiangsu	Port candidate in Jiangsu for offshore wind focus
4	First three China trips	Goldwind headquarters (HQ)	February, 2014	Beijing	HQ discussions on market development and O&M
5	First three China trips	China Wind Power	October, 2014	Beijing	China's premier wind conference, conducted annually in Beijing
6	First three China trips	China Ocean Shipping Company (COSCO)	October, 2014	Guangzhou	Opening of case access
7	Last two China trips	Case OEM Shanghai sales office	July, 2015	Shanghai	Formal interviews
8	Last two China trips	Case OEM HQ and manufacturing facilities visit	July, 2015	Shainghai, Jiangyin, Jiangsu	HQ discussions and WTG manufacturing facilities site visit of case OEM
9	Last two China trips	Non-Chinese blade manufacturer	July, 2015	Jiangyin, Jiangsu	Blade manufacturing supplier to case OEM
10	Last two China trips	Jiangyin port	July, 2015	Jiangyin, Jiangsu	Export port for case OEM nacelles and LM Windpower blades
11	Last two China trips	Longyuan Rudong Intertidal Trial Offshore Wind Farm	July, 2015	Rudong, Jiangsu	Test OWF of Longyuan with 9 different OEMs and 10 different foundation types represented
12	Last two China trips	Haili Wind Power Equipment Technology	July, 2015	Rudong, Jiangsu	Tower and monopile manufacturing facilities of Haili
13	Last two China trips	Jiangsu Longyuan Zhenhua Marine Engineering	July, 2015	Nantong, Jiangsu	Offshore wind engineering, procurement, construction, and installation (EPCi) type JV between Longyuan and ZPMC division of China Communications Construction Company (CCCC) with focus on shipping and logistics/EPCi
14	Last two China trips	China Wind Power	October, 2015	Beijing	China's premier wind conference, conducted annually in Beijing
15	Last two China trips	Tianjin Economic Development Area	October, 2015	Tianjin	China's third major export processing zone after Guangdong and Pudong
16	Last two China trips	Non-Chinese WTG gear sub-supplier	October, 2015	Tianjin	Gear sub-supplier manufacturing facility in Tianjin
17	Last two China trips	Non-Chinese WTG cooling systems sub-supplier	October, 2015	Tianjin	Cooling systems sub-supplier manufacturing facility in Tianjin
18	Last two China trips	Tianjin Orient Container Terminal	October, 2015	Tianjin	DP World container terminal in Tianjin
19	Last two	Shanghai Haitong	October,	Pudong,	Wallenius Wilhelmsen Logistics Roll-

	China trips	International Automobile Terminal	2015	Shanghai	On/Roll-Off terminal in Shanghai where e.g., GE wind modules are frequently shipped from
20	Last two China trips	Case OEM Shanghai sales office	October, 2015	Shanghai	Formal interviews
21	Last two China trips	Case OEM HQ and manufacturing facilities	October, 2015	Shanghai and Jiangyin, Jiangsu	HQ discussions and WTG manufacturing facilities site visit of case OEM
22	Last two China trips	Non-Chinese blade manufacturer	October, 2015	Jiangyin, Jiangsu	Blade manufacturing supplier to case OEM
23	Last two China trips	Longyuan Rudong Intertidal Trial Offshore Wind Farm	October, 2015	Rudong, Jiangsu	Test OWF of Longyuan with 9 different OEMs and 10 different foundation types represented
24	Last two China trips	COSCO Nantong	October, 2015	Nantong, Jiangsu	Shipyard of the COSCO Group with experience in constructing wind turbine installation vessels (WTIVs)
25	Last two China trips	Jiangsu Longyuan Zhenhua Marine Engineering	October, 2015	Nantong, Jiangsu	Offshore wind EPCi type JV between Longyuan and ZPMC division of CCCC with focus on shipping and logistics/EPCi

The total number of 143 encounters [62] forming part of our China case study is presented in more detail in Table 3 and in addition, Table 4 offers a listing of a select portion of the participant observation site visits in more detail. As part of the overall research design, the Danish nation state apparatus/infrastructure has been successfully applied to develop networks abroad. For example, dialogue with and intense collaboration enjoyed from the Danish Foreign Ministry through their Embassy network, including the Danish Trade Council as well as their Innovation Center Denmark organizations, has proven useful to establish relations. Traveling as part of official Danish government delegations has also worked very effectively to create a network of relevant firms and people [63]. Given the five Asia visits performed at different times of our 33-month China case study, a broader reach could be established with our primary empirical data collection efforts (see Tables 2–4). The 15 formal interviews enabled the creation of a gap analysis for China offshore wind as of early 2016 which is presented in Sections 5.3–5.5 of this research.

### 3.2. Our Asian Case Study Work outside China

In terms of work on offshore wind in Asia not directly associated with China itself, the efforts rendered within this project may be summarized at a high level as follows:

- Due to the very costly nature of travels to and within *Japan*, our efforts to understand the Japan market for offshore wind have been rendered remotely and our analysis and results have as of now not been widely disseminated.
- Our efforts to understand the market potential of offshore wind in *South Korea* as well as the shipping and logistics scene did not materialize to the extent conceived at one point within the research project and the actual analysis results pertaining to South Korea have been described separately [3,11].
- A brief visit to *Taiwan* in 2015 (see Table 2) has been coupled with remote efforts to understand the market there as well as detailed dialogue by phone and email with key Taiwanese partners engaged in offshore wind. In general, Taiwan is very open to foreign direct investment and knowledge sharing. Efforts have been rendered within academia to assist the Taiwanese government to map out the potential for offshore wind electricity generation in Taiwan and to analyze the extreme wind speeds experienced on the West Coast of Taiwan [64]. Also, academia has provided useful answers regarding alternative types of foundations for deeper waters such as modified jacket foundations suitable for local conditions and seabed structures in Taiwan [65]. In addition, simulations including earthquake impact on the jacket foundation piling structure have been performed, duly considering the special soil conditions [66]. The windy South China

Sea has also been studied from the other coast line across the Strait, in China. Chinese scholars have analyzed the special weather conditions with focus on the damage inflicted to offshore wind turbines by typhoons which has been coupled with thoughts on potential implications on WTG design efforts [67]. In addition, implications for wind and waves respectively as seen from a floating offshore wind turbine perspective have been analyzed [68,69].

- Somewhat similar to how the offshore wind market in Japan has been researched remotely, the **India** market has been reviewed remotely in a similar manner as part of this research. As part of wrapping up a separate project on competition and collaboration between Europe and Asia, several final draft versions of a very informative and useful working paper (mimeo) on the wind industry in India were circulated [70,71]. The status of the offshore wind industry in India along with policy considerations for the Indian government to speed up diffusion has furthermore been described very well by Govindan and Shankar [72]. In addition, a total of four interviews about the Indian market have been performed in Asia as well as in Denmark as an extended part of this research.

### 3.3. *The Journey across Many Bridges to Reach Our Embedded Case Study Panacea*

The on-site case study research within China itself forming directly part of this research consisted of three main phases of primary empirical data collection efforts:

- (a) Building bridges to form a platform of relations: The first three of the five primary empirical data collection trips to China (the trip which took place during 2013 and the two trips in 2014—see Table 1) were utilized in order to build ‘bridges’ into the Chinese offshore wind energy industry including the opportunity to perform participant observation site visits to key locations, firms, and events. The lens applied was shipping and logistics as the ‘access point’ enabling the discussions. A total of 47 semi-structured interviews and 6 participant observation site visits [62] made up the empirical data collection foundation assembled during these initial trips (see Table 3). The interview part of the encounters made use of interview protocols with open-ended keywords [60,63] to enable a smooth flow of conversation as the interview settings were often informal and always semi-structured and iterative in nature [11]. This work was rendered in order to be able to understand the shipping and logistics aspects of Chinese offshore wind in more detail.
- (b) Understanding China as seen by non-Chinese constituencies: The two-month stay in China of the associate researcher during the first half of 2014 was designed mainly in order to understand the Chinese wind market as seen through the lens of non-Chinese firms and non-Chinese people in China. Again, focus going in was put on shipping and logistics as the ‘access point’ (see Table 5 for details).

The interviews of the associate researcher were designed as iterative and semi-structured interviews which concurrently developed as more empirical data was amassed and analyzed [62]. This part of the overall research design was made in such a way that the 41 semi-structured interviews performed would contribute to a primarily non-Chinese understanding of key developments that occurred in the past [63], mainly in terms of providing a contextual understanding of the revolutionary development of the onshore wind market in China as well as a to serve as a point of departure on the future of the more steadily progressing evolution of offshore wind in China.

- (c) Embedded case study: The remaining two of the five primary empirical data collection trips to China were conducted during July and October, 2015 in parallel with a European case study [3]. The initial relationship platform created in China had resulted in several full case studies now being available. The two most prominent case studies included that of a major SASAC-controlled CSOE shipping firm and that of a leading private Chinese WTG OEM. The leading Chinese WTG OEM case study opportunity was chosen as the embedded case study [60,61] as it was believed to hold the promise and potential to bring unparalleled insight into the layering of buyer-supplier relations [73] of offshore wind in China by the OEM providing case access to

their customers as well as suppliers [61]. This embedded case study was executed during the last two primary empirical data collection visits to China (see Tables 2–4) and comprised a total of 15 structured interviews using a bi-lingual interview guide as well as a total of 34 participant observation site visits [3,62,63].

**Table 5.** Secondary empirical data collection efforts in China.

Research Design	Number of Firms	Firm Split (Percentage)						
Danish Firms/Danish Personnel	25	61.0%						
Chinese Firms/Chinese Personnel	16	39.0%						
	41	-						
Organizational Levels	Developers	WTG OEMs	Shipping/logistics/ports	BOP Manufacturing	Sub-suppliers	Offshore Wind Farm	Other Supply Chain	Total
Top management in China	-	-	4	-	5	-	2	11
Middle Management in China	-	2	3	-	4	-	9	18
Execution layer in China	-	-	2	-	-	-	10	12
Site layer in China	-	-	-	-	-	-	-	0
Total	0	2	9	0	9	0	21	-
Grand total	41	-	-	-	-	-	-	-

## 4. Contextual Analysis

This research is based partly on our empirical case study findings as well as a separate contextual study on the legislative framework and background at a policy level in China to be able to bring a macro level and geopolitical understanding forward. The contextual analysis is presented in Sections 4.1–4.3, which follow here. This is superseded by Section 4, which presents an analysis of the empirical data collected as part of the case study.

### 4.1. Contextual Study on Legislative Framework and Policy Level Background

A number of macro level policy observations which were partly identified during the first two trips to China and also detailed in parallel within academia [1,6,74–78]. These early observations were further probed for during the interviews performed by the associate researcher with non-Chinese individuals and the observations coupled with the secondary empirical data collection efforts had very significant impact at firm level and thus became part of shaping this research further. A summary of the macro level policy observations may be provided as follows:

- Particularly the government of Denmark assisted the Chinese government to *set up the administrative infrastructure for renewable energy* in particular and wind energy in general. As such, the China National Energy Administration of China is very much modeled after the Danish Energy Administration [79,80].
- As the initial targets for wind energy diffusion were set by the Chinese government essentially creating a 4-phased evolutionary path of the onshore wind industry much akin to the generic ILC taxonomy [1], three *wind energy deployment ‘accelerators’* were put in place at a macro/policy level:
  - (1) A set of rules, regulations, and incentives were organized at a policy level to help administer, deploy, and support the wind energy diffusion [1,76,78].
  - (2) A number of firms controlled directly by the Chinese government were given objectives in terms of adding renewable energy capacity [81,82].
  - (3) To leapfrog the wind energy technology barriers of entry [1,76] Chinese firms were mandated by the Chinese government to either forge strategic partnerships with foreign firms in China or acquire firms overseas [74–78,83].

In 2011, the Chinese Ministry of Commerce and other ministerial departments jointly issued “*The opinions for promoting the internationalization development of strategic emerging industries*” and a year earlier, seven industries including that of the ‘New Energy Industry’ had been identified by the State Council as such strategic emerging industries [78]. Expanding on the account by Zhang et al. [78], the ‘strategic emerging industries’ should achieve the internationalization development by:

- (1) promoting the market competitiveness at industry level,
- (2) improving the internationalization capabilities of firms,
- (3) creating a support system at the institutional level, and
- (4) ensure a domestic foundation is in existence for the strategic emerging industries in the form of a strong Chinese domestic home market.

To accelerate indigenous innovation capacity building, the strategic emerging industries had been directed to put emphasis on collaboration with overseas research institutes and industry clusters as well as the setting up of overseas research and development (R+D) centers. For the wind industry, the above mentioned 2011 ministerial decree [78] stipulated that JV formations, equity investment, and M&A transactions would be particularly encouraged by the government and institutionally the banks were needed in order to support this in terms of financing. The banks were decreed, e.g., by the 2015 “*Guidelines on risk management of commercial bank merger and acquisition loans*” issued by the China Banking Regulatory Commission [53] to



support the internationalization efforts. Accordingly, the Chinese banking sector, led by China Development Bank and Export-Import Bank of China, as well as commercial banks such as Bank of China, Bank of Shanghai, China CITIC Bank, and Bank of Communications, was mobilized by the Chinese government and this led to increased outward cross-border M&A activity by the Chinese wind energy industry. As detailed Zhang et al. [78], China Development Bank funded the United States Dollars (USD) 2.2 billion investment on the part of Sinovel to form the JV with Ireland-based Mainstream to be part of the global wind energy scale and scope created by Mainstream. Later on, the series of China Three Gorges (CTG) ventures with Energias de Portugal (EdP) was also funded by the China Development Bank, as outlined below.

- No *offshore wind feed-in tariff* (FIT) existed for offshore wind up to June 2014 where it was finally implemented by the central government [3,5].

#### 4.2. Policy Drivers Correlated to Specific Firm Behaviour in the Chinese Wind Energy Industry

At a firm level, these strategies set out by the Chinese government at the industry level meant that based on the prospects for the Chinese wind market, overseas firms such as Vestas [1], Gamesa, and GE orchestrated onshore wind market entries with a domestically focused manufacturing footprint. In 2006, those three firms enjoyed a 23.6, 15.9, and 12.7% onshore wind market share in China respectively [84].

Conversely for Chinese firms, a number of implications arising from the government accelerator strategies can be evidenced by the following analysis performed separately after the conclusion of our empirical data collection efforts in China:

- In terms of M&A activities of Chinese firms, academic research analyzing 512 outward M&A deals by Chinese firms across 36 industries showed that developing Chinese firms are more likely to acquire overseas firms in industries with a high technology intensity and where a technology gap exists favouring overseas firms [83]. Within the wind industry, the most prominent recent examples with a direct bearing on offshore wind are those of SASAC overseen CSOE developers/operators China General Nuclear (CGN), CTG, and State Development and Investment Corporation (SDIC). Onshore wind antecedents to these recent offshore wind M&A cases include the internationalization efforts of Goldwind, HydroChina, United Power/Longyuan, Beijing Construction Engineering Group, and the significant investment made by Sinovel into the JV with Ireland-based global wind farm developer Mainstream [77]. Some academic studies have been made to understand the decision process within Chinese firms when making such outward cross-border M&A transactions across several emerging economies including China [85,86] and specifically for the Chinese wind energy industry [78]. Conversely, the rationale of European target firms selling to Chinese firms was analyzed academically across five firms sold to Chinese firms in a German setting [87].
- CGN is a South China-based utility that has completed a partial IPO in Hong Kong which confirmed the intent to also diversify in the area of renewables. CGN recently completed the acquisition of 14 onshore wind farms in Ireland for Euro (EUR) 350 million [88,89].
- CTG is the operator of the Three Gorges Dam in China and CTG has set aggressive renewable energy targets for 2020. By the end of 2011, CTG entered into a strategic partnership pertaining to renewable energy [81,82] with EdP. In the strategic partnership, CTG was first to take over a 21.35% share in EdP for EUR 2.7 billion [90]. The stake in EdP was acquired by CTG from the Portuguese government as part of a privatization process of EdP. Subsequently, CTG was to acquire existing fully operational and/or ready-to-build/projected renewable energy projects for EUR 2 billion [82]. Last but not least, CTG was to ensure that a 20-year credit facility of EUR 2 billion be orchestrated by the China government backed lender, China Development Bank [91]. The different parts of the strategic partnership have since been executed including CTG investments in EdP renewable energy assets in Brazil hydro power [92] as well as EdP shares in power generation and distribution assets in former Portuguese colony in Asia, Macau [93]. Within the offshore wind segment, an investment by CTG via an EdP subsidiary of 30% of the shares in

the ready-to-build Scottish 1+ GW OWF, Moray [94]. A similar investment in a ready-to-build OWF project in France has been jointly announced by EdP and CTG for early 2017 [95]. Separate to the EdP deals, CTG has acquired 80% of already operational 288 MW German OWF MeerWind Süd/Ost from US private equity firm Blackstone [96,97].

- **SDIC** acquired the UK-based offshore wind business of Spain's Repsol [98] for EUR 238 million [99]. This acquisition gave SDIC 100% control of the 784 MW Inch Cape OWF project and a 25% stake in the 588 MW Beatrice OWF project. The Beatrice OWF project achieved financial close in 2016 [100] and the partners of SDIC in Beatrice are SSE (40%) and Copenhagen Infrastructure Partners with 35% [101].
- Other and less prominent and technology infusion [75] driven M&A examples include the *Goldwind* acquisition of Vensys in Germany (for the full Goldwind internationalization case study up to 2013, see Zhang et al. [78]), the *XEMC* acquisition of Dutch OEM Darwind [102], the *Titan* acquisition of a tower factory in Denmark from Vestas, and the *CASC Direct* Chinese market JV with Dutch EWT.
- Establishing R+D centers overseas is commonly done in an organic manner as exemplified by *Envision*, *Ming Yang*, and most recently *Goldwind* [103] who have all set up R+D offices in Denmark.
- Several Chinese OEMs make use of technology transfer partnerships and as an example, this includes *Ming Yang*, *Shanghai Electric*, and *Zhejiang Windey* [104], who have all formed partnerships with Germany-based Aerodyn as well as *Dongfang Electric* and *Sinovel* who each respectively formed a partnership with American Superconductors.
- Overseas investments outside China to build organic manufacturing plants to perform final assembly of partly Chinese-constructed wind component in Europe have also been done. Most prominently this was announced and set-up by the *Jiangsu Hantong* shipyard group as they set up their EUR 50-million investment in Jade Werke in Wilhelmshafen, Germany [105] to construct/perform final assembly of steel foundations for OWFs [106]. However, due to the fluctuating offshore wind plans of the German government, the plans were not finalized and the manufacturing facility not finalized [107].

#### 4.3. Review of the Revolutionary Diffusion of Onshore Wind in China

In parallel with the market entry of foreign firms, the Chinese onshore wind market gave birth to a high number of local OEMs which, according to our detailed analysis performed as part of the field trips with support from Chinese Renewable Energy Industries Association and our research partnership with Chinese Wind Energy Association, reached a number as high as 71 by the peak in 2014 (see Table S1.). This compares to other academic research which determined that 28 OEMs who could either produce, sell, and/or install a full prototype WTG by 2012 [78]. Building further on this, Chen et al. [76] discuss entire wind turbine system integrators versus component provider manufacturers. In line with ILC theory (see Section 2.2), the growth phase of the Chinese onshore wind market could not sustain this very high amount of Chinese OEM constituencies coupled with some 10+ foreign OEMs also operating in China and a shake-out took place as also observed by Dai and Xue [1] in their description of the 4 ILC-type phases of the industry development. A granular review up to 2010 also deals with some of these life-cycle phases [74]. Chen et al. [76] provide a detailed account of how the technology base of Chinese OEMs was created and also characterizes the onshore industry evolution using four life-cycle phases framed in the 'business ecosystem lifecycle'. This view is further supplemented in terms of development of intellectual property rights (IPR) and patents by Zhou et al. [108]: According to the detailed analysis based on the empirical findings of this research, many of the Chinese OEMs only reached a prototype R+D stage as opposed to serial production, some of the privately funded firms only received a certain level of investment, and others again stopped production after a while after which they exited the market (e.g., Hanwei, Baonan Machine, and Sinovel Wind Group Co., Ltd.).

Several overseas firms with a strong wind energy technology base chose to enter the seemingly booming Chinese onshore market for wind energy in different ways:

- US-based **GE Energy** (GE) first entered the Chinese wind market with a wholly owned foreign enterprise (WOFE) strategy including a fully owned wind turbine manufacturing plant in Shenyang. In 2010, GE and long-term GE China gas turbine partner Harbin Electric announced the formation of two wind turbine OEM JVs in China where Harbin would take over 49% of the GE onshore plant in Shenyang and GE would take over 49% of a new Harbin offshore plant in Zhenjiang in the Jiangsu province of China. The JVs were ended by mid 2013 [109] with GE citing “...fundamental differences in commercial priorities and business strategy...” as the reason for the JV dissolutions [110]. Pursuing the Chinese wind market separately hereinafter, GE took back over 100% of their Shenyang plant and Harbin gained 100% control over the Zhenjiang plant.
- Before the merger of Siemens Wind Power and Gamesa, now Spain-based **Siemens Gamesa Renewable Energy** (SGRE) first had the Siemens Wind Power business enter the Chinese wind market with a WOFE strategy including a brownfield factory set-up the Nanhui (formerly Lingang) district of the Eastern part of Shanghai. Near to other fossil fuel JV manufacturing sites with longstanding Siemens Group JV partner in China, Shanghai Electric [111,112], the first SGRE WOFE blade manufacturing site was opened in 2010 [113]. However, already in 2011, two JVs for wind energy in China were entered into with Shanghai Electric [114–116] which came into effect in 2012 [117,118]. Towards the end of 2014, Shanghai Electric publicly stated at the China Wind Power conference in Beijing that the “...complex structure of the joint ventures resulted in great operating difficulties, high administrative costs and low efficiency...” [84] and this was also conveyed by Shanghai Electric in public elsewhere [118]. During 2015, SGRE (then Siemens Wind Power) pulled out of the domestic Chinese wind energy market and licensed its’ core WTG technology to Shanghai Electric [119]. SGRE maintained an export focused WOFE manufacturing footprint e.g., for blades in Nanhui.
- Denmark-based **Vestas** entered the Chinese wind market with a WOFE set-up and has not deviated from this strategy, however, the China manufacturing footprint has had to be reduced as demand decreased over time [120,121].

In the case of Vestas, the China market entry was coupled with a seemingly forced market entry of the top European sub-suppliers of the firm. One sub-supplier interviewed by the associate researcher explained:

*“Vestas was one of our biggest customers in Europe and they asked us to join them and enter the Chinese market when they [Vestas] did. At that time, local Chinese regulations apparently stipulated that a minimum of 70% nationally produced content form part of the wind turbines produced by foreign firms with a WOFE set-up in China”.*

In the case of SGRE and GE, the JV set-ups did not fare as originally intended and some of the root causes for the collapse of these JVs which although not fully understood might be found in the partner selection and partner validation process [46].

To summarize the revolutionary pace of development of Chinese onshore wind, please refer to Table 6.

**Table 6.** Chinese onshore wind development growth factor and compound annual growth rate (CAGR) compared to development of onshore wind in the US, Europe, and globally (Source: Own construct using own database based on several sources, such as BTM, BTM a part of Navigant, FTI Consult, Global Wind Energy Council, EIA, [7,74,84]).

Onshore—Installed Capacity (MW)	2000	2005	2010	2015	Growth Factor (2015 over 2000)	CAGR (2005–2015)
China	346	1260	44,781	145,513	420	60.8%
Europe	12,887	40,898	86,619	147,099	10	13.7%
USA	2578	9149	40,298	74,744	28	23.4%
Globally	17,400	59,091	198,065	436,308	24	22.1%
China share in % of globally installed	2.0%	2.1%	22.6%	33.4%	-	-

## 5. Empirical Data Collection Analysis

The primary empirical data collected on the Chinese onshore and offshore wind markets enabled an initial and somewhat early cross case comparison with the European offshore wind market [11] which was followed up by a more focused and qualitatively rich supply chain readiness comparison of Europe and Asia in a later publication [3]. However, the key contribution of this China offshore wind case study research, presented in full in this paper, is a complete gap analysis of the Chinese offshore wind market with a focus on why diffusion has been slower than planned in the 12th Five Year Plan where targets were not met for offshore wind.

In the following, the analysis of the secondary empirical data collection efforts are presented initially (Sections 5.1 and 5.2) as these initial findings set the scene for the findings of the primary empirical data collection efforts. The China offshore wind industry gap analysis is subsequently presented from three different dimensions in Sections 5.3 (macro level), 5.4 (developer/operator level), and 5.5 (WTG OEM level).

### 5.1. Secondary Data Collection Efforts: Turbine Manufacturer Level

The interviews by the associate researcher produced direction at a general level about a number of WTG OEM topics in China as follows:

- Warranty period. From the interviewees, it was gathered that WTGs were normally sold by OEMs with a 2-year warranty period and that developers would release the last 10–15% of the WTG payment only after warranty period. In other cases, non-Chinese OEMs had given up to 10 years of warranty in China.
- Export focus. Several Chinese OEMs wanted to export WTGs to other parts of the world. Several strategies were quoted in the interviews. One interviewee stated that “...one OEM had developed a strategy where they plan to start with the outer areas of Europe like Turkey. Here, less certification requirements exist and they would then work their way in to the core European markets...”. An account of Chinese wind turbine exports has also been performed academically [78].

### 5.2. Secondary Data Collection Efforts: Sub-Supplier Level

A number of interviewees were representatives from surviving sub-supplier firms who had joined their respective OEM partners such as Vestas when the China market was first poised to take off. The reason for many colleagues to have failed was advised as being due to the local content regulations (so-called localization rates) introduced in 2003 at 50%, increased to 70% in 2004, and finally abolished in 2009 [1,74]. The sub-suppliers described a series of more specific sub-supplier related topics to the associate researcher as part of our secondary empirical data collection efforts:

- Patents/IPR. Protecting patents and intellectual property rights was listed as a key concern by many non-Chinese interviewees and has also been dealt with extensively by academia [2]. One detailed academic analysis comprising 17 WTG OEM firms with a more elaborate perusal of 6

sample firms concluded that based on their first-mover advantages from the European wind market, several European firms seemed to possess the dominant design but later Chinese market entrants caught up to the European firms in terms of number of patents filed on an annual basis [108] which could indicate the emergence of a separate dominant design [26] in the Chinese submarket [27]. One European sub-supplier explained to the associate researcher that “...during the first years, we did business with all top ten Chinese OEMs. However, they bought in very low quantities from us. Afterwards, we only continued to do some substantial business with one OEM, later two...” and this has been depicted graphically as an evolution of firms’ networks in Zhou et al. [108].

- Payment terms. Many non-Chinese interviewees stated that cash-flow was challenging in the Chinese market. One sub-supplier stated that “...payment terms from developers and OEMs could often be 6-12-18 months and this makes it challenging to run the business...”. Within academia, a comprehensive recent literature review covering supply chain integration [122] identified only one paper [123] that deals with integration of the financial supply chain into the supply chains that deal with the movement of goods as well as information/documentation.
- ‘Us’ and ‘Them’. From our interviews, it was clear that the China-based management of the Chinese subsidiaries of non-Chinese firms often felt that they were very often “...left to be very alone...” with the complex Chinese market and that their overall situation was “...not well understood...” by their corporate colleagues back at the corporate offices in e.g., Europe.

The Chinese onshore market developed in such a way that overseas OEMs lost market share very quickly. By 2013, the market shares of Vestas/Gamesa/GE had dropped to 3.2%/1.6%/1.1% respectively [84]. This also meant that of the 100 or so sub-suppliers who joined Vestas on their China journey, the interviewees generally agreed that only some 20% remain in China today [121] as many of these non-Chinese firms formed part of supply chains of the overseas OEMs as opposed to the Chinese OEMs who had different supplier networks [6,76,108].

From the interviews performed by the associate researcher in China, initial knowledge of the gaps in the Chinese offshore wind market was amassed through the empirical data collection efforts. However, this was the view on gaps in the Chinese wind market as seen by non-Chinese firms and non-Chinese representatives: A Chinese view would be more valuable and display a more realistic view of the world and in the following three sections (Sections 5.3–5.5), the Chinese view will be presented as obtained from the primary empirical data collection visits to China including the embedded case study with the 15 formal interviews.

### 5.3. Primary Data Collection Efforts: Macro Level China Offshore Wind Industry Gap Analysis

The obvious macro level gap is a conundrum in itself for readers with a non-Chinese background: Why did the Chinese government simply not use greater force to make Chinese SOEs execute the plans comprised in the 12th Five Year Plan? One of the recent and very extensive research efforts on China (offshore) wind looked at exactly this [5] and concluded that a stand-off between the government and the SOEs was on-going for a long time [124]. The answer as derived from the empirical data collection efforts of our case study work is that SOEs have strict earnings targets imposed upon them by the very same nation state responsible for the Five Year Plans. It was therefore not until the implementation of the new central government defined offshore wind FIT in June 2014 that those profitability targets came close to being realizable for Chinese firms, SOEs included [3]. This FIT had been called for by academia (and industry) for a long time as reviewed in Poulsen and Lema [3]. Incidentally, provinces are independently allowed to add incremental FIT incentives on top of the central FIT as they deem to be of value.

The pace of construction has since then picked up quite dramatically (see table 8), initially fueled by the fast-tracking given to 44 potential offshore wind farm projects with the December 2014 “National offshore wind power development and construction program (2014–2016)” decree issued by the National Energy Administration [125]. However, fear exists especially on the part of Western observers that China will repeat Europe’s early ILC teething problems of installing onshore wind

technology in the rough and harsh offshore environment with salt, water, and corrosion challenges faced [3]. In our primary empirical data collection work in China, this stance was largely confirmed also by the Chinese OWF operators and OEMs with offshore wind test install bases. Towards the end of 2015, operators of Chinese onshore wind farms started to openly reveal even in conference and seminar settings that the lower prices of Chinese onshore WTGs also had the adverse effect that severe O&M challenges were being faced [3]. In private talks and during interview sessions, it was indicated that Chinese OEMs had built onshore WTGs to be able to last closer to 10 years as opposed to the 25-year operations span expected from a European WTG and this was to some extent confirmed also within academia [2].

**Table 8.** “National offshore wind power development and construction program (2014–2016)” compared to original 12th Five Year Plan offshore wind targets, by province (Own construction based on [125]).

Province	Number of Projects Included in Feed-In-Tariff	Corresponding Capacity in Feed-In-Tariff (MW)	Original 12th Five Year Plan Target (MW)
Liaoning	2	600	-
Hebei	5	1300	5600
Tianjin	1	90	-
Shandong	-	-	7000
Jiangsu	18	3490	9450
Shanghai	-	-	1750
Zhejiang	5	900	3700
Fujian	7	2100	1100
Guangdong	5	1700	1400
Hainan	1	350	-
Total	44	10,530	30,000

#### 5.4. Primary Data Collection Efforts: Developer/Operator Level China Offshore Wind Industry Gap Analysis

The bilingual interview matrix design applied in China for our embedded case study was centered around a top five, and thereby market leading, Chinese WTG OEM. The WTG OEM case firm opened up their supply chain and provided case access into the mechanics and workings of itself as a firm at both strategic and tactical levels. In addition, our WTG OEM case firm provided case study access to its clients as well as its suppliers in a very focused and direct manner which we helped orchestrate from an overall research design perspective. Due to the fact that the WTG OEM was in a direct business relationship with its clients as well as its suppliers, the interviews and site visits were particularly meaningful, serious, and organized. The WTG OEM firm organized the interviews in such a way that translation from English to Mandarin and/or from English characters to Chinese characters was supplemented in cases where the skills and competencies of the research team did not suffice. Also, the daunting task of the sheer logistics of transporting the research team over great physical distances within China was eased considerably with the support of the OEM firm. The motivation to participate in the case study on the part of the OEM firm was three-fold:

- (1) It was a case of the relationship having been established,
- (2) gaining access to European knowledge/relations, as well as
- (3) the ability to bring a new and academically driven dimension into their already strong and continuously improving client/supplier relations.

Critical knowledge of the composition of the Chinese offshore wind supply chain was obtained: This was directly comparable to the structure of the European offshore wind supply chain and from a shipping/logistics scope contrasting perspective, one major example was that of the WTG offshore transportation and installation scope [3]. WTG transportation and installation tasks were insourced by the developers in China whereas in Europe, the structure of having the WTG transport, installed, commissioned, operated, and maintained by the WTG OEM has been the precedent for many years. Chinese developers/operators were very clear on their motivation to structure the supply chain with

more control residing in-house with them in an insourced manner: Over time, the large Chinese SOEs involved in OWF construction and operations wish to align with the Five Year Plan vision to be able to export turn-key OWFs including WTGs and BOP components in a fully installed, turn-key manner including full life-cycle operations and decommissioning [3].

With this radical industry vision for China offshore wind as our back-drop, our empirical data collection efforts in China were rendered mainly with shipping and logistics as the stated objective of our research. However, our interview guide was deliberately structured much more broadly as we also had a vested interest in understanding the overall wind market, the dynamics, and the objectives going forward. Our case study with Chinese firms and based on interviews with Chinese nationals revealed a series of critical gaps faced by the Chinese offshore wind industry by early 2016.

From a developer and operator perspective, the following items were identified during our research:

- **European showcase construction** of OWFs in China. At government level and also at SOE level, a wish was put forward for a European OWF developer to construct and operate an OWF in China based on European standards but subjected to Chinese conditions.
- Full OWF life-cycle **cost modeling** capabilities. At the project approval stage, critical capabilities around cost modeling for the entire life-cycle of an OWF were sought also including the O&M and de-commissioning life-cycle phases.
- Full OWF life-cycle **project planning** capabilities. From a project planning perspective, tools and IT systems were mentioned as critical gaps. One developer expressed that “...we will construct the offshore wind farm in less than 18 months which matches the standards set in Europe...” but when asked how long the project had been in planning phases, the answer was eight years.
- Full OWF **risk management and insurance** capabilities as well as experience. Risk management was mentioned as a critical factor for OWFs as these projects are not yet well understood. Insurance as an option to cover risks was discussed and it could be particularly relevant for private operators and SOEs alike. However, not much risk management and insurance underwriting experience exists for OWFs in China yet.
- **EPCi firms** willing to bring experience from Europe to China. The ability to buy a turn-key and fully engineered, procured, constructed, and installed OWF is something some of the SOE developers aspire to become able to sell as an export package in the future. However, to gain such experience in China, a wish was expressed to have overseas EPCi firms enter China with this experience from the offshore wind sector. One Chinese EPCi representative expressed that in driving past an offshore WTG with the Group CEO, the head of their, at that time, troubled offshore wind division had received a comment from the CEO as follows:

*“We build bridges, cranes, and ships. How can a small wind turbine generator like that cause us this amount of challenges?”*

A good answer did not exist to this challenge from the CEO...

- **BOP supply chain** infrastructure and experience. The BOP supply chain was not very built out in China. As an example, it was not until 2015 that the first offshore substations (OSS's) were needed and subsequently imported into China for installation. According to ABB [126], they delivered the first OSS to CTG's Xiangshui Offshore Wind Farm. At the same time, also the Huaneng/Huadian JV OWF Rudong Baxianjiao Offshore Wind Farm [127] as well as CGN [128] have been eager to take credit for OSS's and foundations that were installed as China-first and Asia-first milestones respectively. Similarly, export cables and array cables represent challenges in the China BOP supply chain.
- **Decommissioning** experience and calculation methods. The decommissioning life-cycle phase was now being considered according to our research. One developer explained that they are now considering how to do this in an onshore setting and that “...offshore decommissioning is much more complex. We need to consider this from the beginning as our projects are planned”.

### 5.5. Primary Data Collection Efforts: Turbine Manufacturer Level China Offshore Wind Industry Gap Analysis

In terms of topics specific only to WTG OEMs, our research indicates that support with manufacturing facility design, optimization, and management experience is sought after in China. This was cited due to the fact that the wind industry is still young and that efficiencies are therefore sought after.

From developers and OEMs alike, a series of WTG related challenges were commonly mentioned:

- **Partnerships with European firms** to customize European experience to the unique Chinese conditions. In general, Chinese constituencies interviewed expressed that they did not see a direct application of European knowledge, technology, or assets into the Chinese market: A certain degree of customization to China would be necessary and this would be one of the tasks for which a Chinese partner of a collaboration constellation would be ideally suited. Chinese interviewees expressed concern about overseas solutions being too costly, inefficient, and not sufficiently focused on the Chinese SOE social responsibility to also generate jobs locally in the provinces where the OWFs are constructed.
- **O&M concepts, experiences, and factual operational data.** Significant challenges were faced by operators of onshore wind farms and this was shared rather openly with photos and commentary during public conferences [3]. Based on these challenges onshore [2], knowledge of O&M from a conceptual design as well as an actual operations perspective was actively sought. Offshore wind O&M experience coupled with actual operational data were key dimensions sought by developers as well as OEMs alike.
- **Offshore native WTG technology** able to withstand the harsh offshore environment. Especially in the South, harsh weather including typhoons had long had a severe impact on onshore WTGs. Relevant experience particularly from the North Sea was sought in terms of typhoon impact prevention. Similarly, for icy conditions, especially experience from the Baltic Sea Region was sought.
- **Offshore wind turbine foundations.** Especially in the porous inter-tidal OWF development zones for the Yellow River, Yangtze River, and Pearl River, demands for different offshore wind foundations have been very apparent. Especially the Longyuan Rudong Intertidal Trial Offshore Wind Farm features more than 100 WTGs made by 10+ OEMs including SGRE, Sinovel, Goldwind, CSIC Haizhuang, Dongfang Electric, Envision, United Power, Ming Yang, SANY, SEwind, Wuxi Baonan, and XEMC. As observed during our visits to the OWF in 2015, each offshore wind OEM has tested several WTG designs and in some cases also several foundation designs. OWF operator Longyuan has patented a solution to eliminate the transition piece between the foundation and WTG [129,130].
- **Shipping and logistics** knowledge, processes, and experience across all life-cycle phases. This part was particularly expanded upon due to this forming the crux of our interview protocol and because shipping and logistics topics were presented in advance of the interviews as our key reason for wanting to take up time of the interviewees. In the development & consent OWF life-cycle phase [12], studies of road conditions and studies of seabed conditions were cited as critical areas where exchange of information with overseas counterparts could be of use. In addition, studies of the environment and animal protection opportunities were also cited as key development and consent opportunities for collaboration. In general, vessels based on European operations experiences were sought. However, it was highlighted that such vessels would need to be customized for the unique Chinese OWF set-ups with focus on inter-tidal, river delta, near shore, and 10-10-10 definition (the 'double-ten' or '10-10-10' standard) of the China State Oceanic Administration [128] across the different OWF life-cycle phases [12]. Specific vessel knowledge including piling hammer vessels, cable laying vessels, and WTIVs (installation and commissioning life-cycle phase [12] of an OWF) and crew transfer vessels (O&M life-cycle phase) was commonly requested along with specific capabilities and skills such as jacking, dynamic



positioning, and craneage. Especially in terms of the quite expensive WTIVs, overseas investments to bring both experience and assets to China were sought: In terms of WTIVs, a gap existed in terms of capacity necessary for China to complete the construction of the 44 OWF projects [125] within the new June, 2014 implemented central government FIT stipulations [3].

## 6. Discussion

Getting to the 15 structured and formal interviews in China supported by participant observation sit visits was not trivial (see Sections 2.5 and 3). As with any other market, significant knowledge and understanding of local issues is necessary on the part of the researcher in order to make a good interviewer who can be part of the conversation with, in this case, the Chinese interviewee counterparts. Perhaps more so in a Chinese setting:

- First, to understand ‘local’ issues in a country with almost 1.4 billion inhabitants is also no small task. To some extent, offshore wind in China can be seen as the three distinctively different regional areas as in the North, Central, and Southern parts of the East Coast of China where particularly the wind speeds differ (similar to the Mediterranean, Atlantic, North Sea, and Baltic Sea conditions of Europe). Within each offshore wind regional area, several provinces exist like Fujian and Guangdong in the South or Shanghai and Jiangsu in the Central offshore wind regions. Within each province, major cities, counties, and ports exist and this geographical and political structure of province/city/county/port may to some extent be compared to a country set-up in Europe or the structures of individual states in the US.
- Second, a barrier of understanding also existed in the form of the language (written and spoken) where especially the more senior generation Chinese often chose to speak and write English only through interpreters which could indicate a power stance [131].
- Third, the idea of getting quoted or cited in academic work was not always very culturally desired for the interviewees as the risk was perceived to be great in terms of saying something which may be quoted wrongly and/or could be interpreted as criticism of the firm, the country, and/or colleagues.
- Fourth, respect of Chinese ways of interacting and the construct of the concurrently developing personal relations deserves mention.
- Finally, cultural topics such as general Chinese protocol and etiquette may seem insignificant but should not be omitted.

The analysis presented in this research provides insight into how the Chinese government systematically decrees state-owned Chinese firms to expand into overseas markets for select emerging industries [78] of strategic importance to China. Overseas expansion is driven by a government decreed desire on the part of China to speed up learning efforts at a national level. The systematic alignment of policies, financing options [53], and particularly SASAC-controlled CSOE firm policy including the use of M&A [81,82,88,89] described in this research has provided an example of how China may deliberately fast track industry evolution. The nation-level strategic plans and institutional support policies mobilized by China described in Section 4.2 are instrumental for the Chinese wind industry in order to be able to conquer market shares internationally by initially building a strong home market and then facilitating an end-to-end export solution. Essentially, exporting a complete offshore wind farm is a turn-key and fully financed complex billion-dollar megaproject [36] with an expected lifespan of 30+ years from the first site preparations start through the completion of the final decommissioning [12].

The analysis presented in this research points to a need for European and Chinese firms to successfully forge long-term alliances in order to quickly close some of the offshore wind gaps in China and benefit from not making the same mistakes as Europe did in the early days of offshore wind pioneering from 1991–2005. Such alliances would have an immediate impact on the domestic Chinese offshore wind market in the short term but also be valuable for future Chinese turn-key offshore wind energy export projects. As successful alliances and partnerships may be studied both

based on in-depth analysis of examples of past efforts that worked well, this research has also presented a rich catalogue of examples of past collaboration efforts not yielding desired results as well.

At policy level, it is important that the evolution of the Chinese offshore wind power industry is fast-tracked in order to somewhat match the (r)evolutionary pace, volume, and velocity which the Chinese onshore wind power industry had demonstrated in the past (see Table 6). Our secondary empirical data collection efforts indicate that the local content rules in place from 2003 through 2009 has not yet been forgotten by a number of especially European firms who either survived or succumbed during the shake-out that incurred as part of the onshore Chinese market development. To repeat such a regulatory regime is agreed by practitioners and scholars [1,74,76] alike to not be necessary nor the preferred path forward not would it seem to be necessary based on the much more mature state of major parts of the Chinese wind supply chain. A more open, engaging, and collaborative environment should be stimulated by the Chinese government in order to forge the partnerships and alliances needed to close the offshore wind industry gaps identified in this research. On the part of governments outside China, support to firms engaged in e.g., the European offshore wind sector should be given and research projects involving also Chinese researchers and firms should be encouraged.

The role of CSOEs under the direct control and oversight of the SASAC cannot be underestimated as a very powerful tool for the Chinese government to execute national policy. Major offshore wind endeavours in China such as the role of CSOE Guodian's Longyuan subsidiary to test 10+ local OEMs against imported SGRE technology off Rudong is a good example detailed above (see Section 4.4). However, also the role of CSOEs CTG and SDIC to amass overseas project experience in Europe (see Section 4.2 above) shows how China is able to use some of the national wealth from its' sovereign wealth fund holdings and dispense this through China Development Bank as in the case of CTG and EdP.

It seems clear from our findings that overseas knowledge was first brought to China for the onshore (r)evolution in various different ways and that this is now also being pursued for the offshore market evolution. The use of M&A at a national level with the involvement of the CSOEs (see Sections 3.1 and 3.2) exemplifies a much more mature political position of the Chinese government in Beijing when it comes to wind energy at this time compared to at the time when onshore wind developments were first initiated.

There seems to be little doubt as evidenced by this research, however, that some of the (negative) experiences gained by non-Chinese investors in the onshore Chinese wind market (see Section 4.3) have left a degree of caution and tension in the market place: After a period of strong local content requirements [1,74], the onshore market is clearly a Chinese-dominated market where the top 10 domestic OEMs account for 81% of the market and the top 3 foreign manufacturers have very small market shares including Gamesa (1.4%) (now part of SGRE), Vestas (0.9%), and GE (0.4%) according to Global Wind Energy Council [132]. In the rest of the world, the wind energy market is open to all OEMs and as detailed by Zhang et al. [78], the Chinese OEMs have started to export their machines overseas to be attain market shares globally [133]. However, the growth of the Chinese home market remains daunting with an install base of 168.7 GW by the end of 2016 [7]. Academic research from another R+D prone industry (pharmaceuticals) suggests that foreign firms should partner with Chinese firms with a predefined and agreed long-term task allocation model duly considering R+D capabilities of foreign firms and access to large-scale human capital on the part of domestic Chinese firms [134]. If expanded upon further, Chinese firms—as well as integrated foreign supply chain partners—would initially benefit from the domestic China market opportunities and later also from Chinese firms exporting from China to other markets wind markets globally.

## 7. Conclusions

The actual achievement of 1 GW of offshore wind installed by the end of 2015 was rather far from the 12th Five Year Plan target of 5 GW at this time. With the revised 13th Five Year Plan goal of

12 GW of offshore wind in operations or under construction by 2020 [135], the ambitions of the Chinese government to have 30 GW in operation by 2020 have been significantly adjusted for offshore wind and installation of 1.6 GW [7] had been achieved by the end of 2016.

Following the onshore (r)evolution of wind energy in China, the offshore wind evolution has been slower due to the lack of a dedicated offshore wind FIT which was only introduced in June 2014 [3]. Following the FIT implementation, the 44 fast tracked projects [125] have been developing quickly based on the support of the central government, provincial governments, municipalities, and local counties. Based on industry sources, many more projects, beyond the initial 44 fast tracked projects, are under now under way and a detailed mapping of the actual pipeline of offshore wind farm projects by province in China could be a very valuable task for other researchers to perform in order to understand exactly how much offshore wind power will realistically be grid connected by when. However, as this research has shown, gaps exist for major Chinese offshore wind constituencies at different levels and we have outlined the key gaps identified at a macro, developer/operator, and turbine manufacturer level. These gaps play a major role in terms of why offshore wind diffusion has not yet picked up the (r)evolutionary speed seen in terms of onshore wind China and each gap identified in this research could therefor form the basis of further study by other researchers.

As in Europe, logistics [12] plays a significant role in offshore wind diffusion. The wind energy constituencies in China realize the importance of shipping and logistics inasmuch as this lens got us the 15 formal interviews that formed the basis of the embedded case study within our overall China offshore wind case study. Logistics is part and parcel of the entire life-cycle of an offshore wind farm and our interview guide with a logistics vantage point yielded a much broader dialogue ultimately able to generate the gap analysis contained in this research (see Section 4.4 above). Moreover, shipping and logistics topics require careful focus and much attention as these derived disciplines within the offshore wind industry represent physical constraints in terms of the ability to speed up diffusion of offshore wind in China.

**Supplementary Materials:** The following are available online at [www.mdpi.com/1996-1073/10/12/2153/s1](http://www.mdpi.com/1996-1073/10/12/2153/s1), Table S1: Chinese wind turbine original equipment manufacturers as of 2014 (Source: Own analysis based on collaboration with Chinese Renewable Energy Industries Association and Chinese Wind Energy Association).

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## Abbreviations

The following abbreviations are used in this manuscript:

BOP	Balance of plant
CAGR	Compound annual growth rate
CCCC	China Communications Construction Company
CGN	Chinese utility firm China General Nuclear

COSCO	China Ocean Shipping Company
CSEO	Central state-owned enterprise overseen by the State
CTG	Chinese utility firm China Three Gorges
EdP	Energias de Portugal
EUR	Euro
EPCi	Engineering, procurement, construction, and installation
FIT	Feed-in tariff
GE	GE Energy
GW	Giga-Watt
HQ	Headquarters
ILC	Industry life cycle
IPO	Initial public offering
IPR	Intellectual property rights
JV	Joint-venture
LSOE	Local state-owned enterprise in China owned by the provincial and/or local municipality government
M&A	Mergers & acquisitions
MW	Mega-Watt
O&M	Operations and maintenance
OEM	Original equipment manufacturer
OSS	Offshore sub-station
OWF	Offshore wind farm
PLC	Product life cycle
PMI	Post-merger integration
PPP	Public-Private Partnership
R+D	Research and development
SASAC	State-owned Assets Supervision and Administration Commission of the State Council in China
SCM	Supply chain management
SGRE	Siemens Gamesa Renewable Energy
SOE	State owned enterprise
SDIC	State Development and Investment Corporation
US	United States of America
USD	United States Dollars
WOFE	Wholly owned foreign enterprise
WTIV	Wind turbine installation vessel
WTG	Wind turbine generator

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